

NF07280US

## ZOOM LENS SYSTEM

The disclosures of the following priority  
5 application is herein incorporated by reference:

Japanese Patent Application No. 2003-016603  
filed January 24, 2003.

BACKGROUND OF THE INVENTION10 Field of the Invention

The present invention relates to a zoom lens  
system.

Related Background Art

Among negative-positive type two-group zoom  
15 lenses, there is a zoom lens using an advanced Gauss  
type lens group as a second lens group having  
positive refractive power (disclosed, for example, in  
Japanese Patent Application Laid-Open No. 55-60911).  
In addition, zoom lenses of this type have been  
20 disclosed, for example, in Japanese Patent  
Application Laid-Open Nos. 8-334694, 9-171140, 2000-  
2837, and 2002-6214).

However, the zoom lens disclosed in Japanese  
Patent Application Laid-Open No. 55-60911 is bulky  
25 and correction of aberration is not satisfactory. The  
zoom lenses disclosed in Japanese Patent Application  
Laid-Open Nos. 8-334694 and 2002-6214 have a large

number of lens elements and are difficult to be  
manufactured. Moreover, the zoom lenses disclosed in  
Japanese Patent Application Laid-Open Nos. 9-171140  
and 2000-2837 have a large number of lens elements,  
5 so they are bulky.

Accordingly, no zoom lens disclosed in the  
above-described patent documents can reach a zoom  
lens system having small number of lens elements,  
high optical performance and compactness, and being  
10 easy to be manufactured.

#### SUMMARY OF THE INVENTION

The present invention is made in view of the  
aforementioned problems and has an object to provide  
15 a zoom lens system having compactness of about the  
size of a single focal length normal lens, small  
number of lens elements, zoom ratio of about 2.9, and  
high optical performance with being easy to be  
manufactured.

20 According to one aspect of the present invention,  
a zoom lens system includes, in order from an object,  
a first lens group having negative refractive power  
and a second lens group having positive refractive  
power. Zooming is carried out by varying an air space  
25 between the first lens group and the second lens  
group. The first lens group includes at least, in  
order from the object, a negative lens and a positive

lens. The second lens group includes, in order from the object, a front lens group having positive refractive power and a rear lens group having positive refractive power. The front lens group includes, in order from the object, a positive lens and a cemented lens constructed by a positive lens cemented with a negative lens. The rear lens group includes, in order from the object, a cemented lens constructed by a negative lens cemented with a positive lens. The following conditional expression (1) is satisfied:

$$0.27 \leq D_s/D \leq 0.8 \quad (1)$$

where  $D_s$  denotes an air space along the optical axis between the most image side lens surface of the front lens group and the most object side lens surface of the rear lens group, and  $D$  denotes a distance along the optical axis between the most object side lens surface and the most image side lens surface of the second lens group.

In one preferred embodiment of the present invention, the following conditional expression (2) is preferably satisfied:

$$0.5 \leq f_b/f_a \leq 15 \quad (2)$$

where  $f_a$  denotes the focal length of the front lens group, and  $f_b$  denotes the focal length of the rear lens group.

In one preferred embodiment of the present

invention, the following conditional expression (3) is preferably satisfied:

$$0 < n_{an} - n_{ap} < 0.45 \quad (3)$$

where  $n_{ap}$  denotes refractive index of the positive lens of the cemented lens in the front lens group at d-line, and  $n_{an}$  denotes refractive index of the negative lens of the cemented lens in the front lens group at d-line.

In one preferred embodiment of the present invention, the following conditional expression (4) is preferably satisfied:

$$0 < n_{bn} - n_{bp} < 0.45 \quad (4)$$

where  $n_{bn}$  denotes refractive index of the negative lens of the cemented lens in the rear lens group at d-line,  $n_{bp}$  denotes refractive index of the positive lens of the cemented lens in the rear lens group at d-line.

In one preferred embodiment of the present invention, an aperture stop for defining an f-number is arranged between the front lens group and the rear lens group.

In one preferred embodiment of the present invention, the following conditional expression (5) is preferably satisfied:

$$v_{1p} < 23.2 \quad (5)$$

where  $v_{1p}$  denotes Abbe number of the medium of the positive lens in the first lens group.

In one preferred embodiment of the present invention, the following conditional expression (6) is preferably satisfied:

$$1.790 < n_{1p} \quad (6)$$

5 where  $n_{1p}$  denotes refractive index of the medium of the positive lens in the first lens group.

In one preferred embodiment of the present invention, the first lens group consists of, in order from the object, the negative lens and the positive  
10 lens. The positive lens has a convex surface facing to the object.

According to another aspect of the present invention, a zoom lens system includes, in order from an object, a first lens group having negative  
15 refractive power, and a second lens group having positive refractive power. Zooming is carried out by varying an air space between the first lens group and the second lens group. The first lens group consists of, in order from the object, a negative lens and a  
20 positive lens having a convex surface facing to the object. The second lens group includes, in order from the object, a positive lens, a first cemented lens constructed by a positive lens cemented with a negative lens, an aperture stop, a second cemented  
25 lens constructed by a negative lens cemented with a positive lens.

Other features and advantages according to the

invention will be readily understood from the detailed description of the preferred embodiment in conjunction with the accompanying drawings.

5     BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram showing the lens arrangement of a zoom lens system according to Example 1 of the present invention together with movement of each lens group.

10     Fig. 2 graphically shows various aberrations of the zoom lens system according to Example 1 in a wide-angle end state when the zoom lens is focused at infinity.

15     Fig. 3 graphically shows various aberrations of the zoom lens system according to Example 1 in an intermediate focal length state when the zoom lens is focused at infinity.

20     Fig. 4 graphically shows various aberrations of the zoom lens system according to Example 1 in a telephoto end state when the zoom lens is focused at infinity.

25     Fig. 5 is a diagram showing the lens arrangement of a zoom lens system according to Example 2 of the present invention together with movement of each lens group.

Fig. 6 graphically shows various aberrations of the zoom lens system according to Example 2 in a

wide-angle end state when the zoom lens is focused at infinity.

Fig. 7 graphically shows various aberrations of the zoom lens system according to Example 2 in an intermediate focal length state when the zoom lens is  
5 focused at infinity.

Fig. 8 graphically shows various aberrations of the zoom lens system according to Example 2 in a telephoto end state when the zoom lens is focused at  
10 infinity.

Fig. 9 is a diagram showing the lens arrangement of a zoom lens system according to Example 3 of the present invention together with movement of each lens group.

Fig. 10 graphically shows various aberrations of the zoom lens system according to Example 3 in a wide-angle end state when the zoom lens is focused at  
15 infinity.

Fig. 11 graphically shows various aberrations of the zoom lens system according to Example 3 in an intermediate focal length state when the zoom lens is  
20 focused at infinity.

Fig. 12 graphically shows various aberrations of the zoom lens system according to Example 3 in a telephoto end state when the zoom lens is focused at  
25 infinity.

# DESCRIPTION OF THE PREFERRED EMBODIMENTS

Basic construction of the zoom lens according to the present invention is going to be explained below.

Generally, in a negative-positive two-group zoom lens, a second lens group having positive refractive power acts as a master lens of a whole zoom lens system. Usually by the effect of the second lens group, an air space (a necessary minimum air space for varying lens group positions) between the first lens group and the second lens group has to be secured for zooming with securing the back focal length. In consideration of reducing the size and manufacturing cost of the zoom lens system, it becomes further necessary to reduce the size and the number of lens elements of the second lens group as much as possible.

There are such lens types, satisfying these requirements, as an Ernstar type, a modified Triplet type, and a Sonnar type having a basic construction of positive-positive-negative-positive power arrangement. However, the lens having any of these lens types has a large deviation angle upon refracting each light ray at each lens surface, so it has a defect that the sensitivity to decentering is high. In other words, when it is manufactured, accuracy of each part has to be increased upon processing and accuracy of adjustment has to be



increased upon assembling, so that it has a defect to increase manufacturing cost.

Therefore, the present invention created a new lens type as a second lens group in a negative-  
5 positive two-group type zoom lens. As described later in each Example, the second lens group in a zoom lens system according to the present invention, basically starting from a Gauss type, may include, in order from an object, a front lens group  $G_{2-1}$  and a rear  
10 lens group  $G_{2-2}$ . The front lens group  $G_{2-1}$  may be composed of, in order from an object, a positive lens, and a cemented lens constructed by a positive lens cemented with a negative lens, and the rear lens group may be composed of a cemented lens constructed  
15 by a negative lens cemented with a positive lens. Otherwise, the second lens group may include a front lens group  $G_{2-1}$  which is composed of, in order from the object, a positive lens, and a cemented lens constructed by a positive lens cemented with a  
20 negative lens, and a rear lens group  $G_{2-2}$  which is composed of a cemented lens constructed by a negative lens cemented with a positive lens, and a positive lens.

The second lens group having these constructions  
25 has a characteristic of a Gauss type that a negative lens locating at the center of a Triplet type is replaced by a pneumatic lens. Moreover, by widen

sufficiently an air space between these two cemented lenses, in other words, a space between the front lens group  $G_{2-1}$  and the rear lens group  $G_{2-2}$  in the second lens group  $G_2$ , refractive powers of the front lens group  $G_{2-1}$  and the rear lens group  $G_{2-2}$  in the second lens group  $G_2$  can be lowered. Accordingly, aberrations produced at each lens surface can be suppressed lower, so that not only designed optical performance can be increased but also optical performance after manufacturing can be stable. The configuration of the second lens group  $G_2$  makes it possible for the zoom lens system according to the present invention to realize high optical performance, an increase in productivity, lowering manufacturing cost, and compactness.

Then, conditional expressions of a zoom lens system according to the present invention is going to be explained.

In a zoom lens system according to the present invention, the following conditional expression (1) is satisfied:

$$0.27 \leq D_s/D \leq 0.8 \quad (1)$$

where when the second lens group  $G_2$  is composed of, in order from the object, a front lens group  $G_{2-1}$  having a positive lens and a cemented lens constructed by a positive lens  $L_{ap}$  cemented with a negative lens  $L_{an}$ , and a rear lens group  $G_{2-2}$  having a

cemented lens constructed by a negative lens  $L_{bn}$   
cemented with a positive lens  $L_{bp}$  and a positive lens,  
 $D_s$  denotes an air space along the optical axis  
between the most image side lens surface of the front  
5 lens group  $G_{2-1}$  and the most object side lens surface  
of the rear lens group  $G_{2-2}$ , and  $D$  denotes a distance  
along the optical axis between the most object side  
lens surface and the most image side lens surface of  
the second lens group  $G_2$ .

10           Conditional expression (1) is for bringing the  
aforementioned effect into full play by the air space  
between two cemented lenses in the second lens group  
 $G_2$ , in other words, the distance between the front  
lens group  $G_{2-1}$  and the rear lens group  $G_{2-2}$ .

15           When the ratio  $D_s/D$  exceeds the upper limit of  
conditional expression (1), the ratio of the distance  
between the front lens group  $G_{2-1}$  and the rear lens  
group  $G_{2-2}$  to the thickness of the second lens group  
 $G_2$  becomes excessively large, so that the thickness  
20 of the front lens group  $G_{2-1}$  and the rear lens group  
 $G_{2-2}$  becomes too thin. Accordingly, it becomes  
difficult to correct aberrations or to accomplish  
high optical performance, an increase in productivity,  
lowering manufacturing cost, and compactness. When  
25 the upper limit of conditional expression (1) is set  
to 0.7 or less, more preferably 0.6 or less, further  
high optical performance, an increase in productivity,

lowering manufacturing cost, and compactness can be accomplished.

On the other hand, when the ratio  $D_s/D$  falls below the lower limit of conditional expression (1), refractive effect of the pneumatic lens formed between the front lens group  $G_{2-1}$  and the rear lens group  $G_{2-2}$  cannot be optimized. Accordingly, in order to keep the state of good correction, refractive power of each lens surface of the front lens group  $G_{2-1}$  and the rear lens group  $G_{2-2}$  becomes strong, so production of aberration increases. Accordingly, it becomes difficult to accomplish high optical performance, an increase in productivity, lowering manufacturing cost, and compactness. In order to correct aberrations preferably, the thickness of each lens element of the front lens group  $G_{2-1}$  and the rear lens group  $G_{2-2}$  can be thick. However, this is against reduction of production cost, and compactness, so that it is undesirable. In order to bring the effect of the present invention into full play, it is preferable to set the lower limit of conditional expression (1) to 0.33 or more, further preferably to 0.35 or more.

In a zoom lens system according to the present invention, the following conditional expression (2) is preferably satisfied:

$$0.5 \leq f_b/f_a \leq 15 \quad (2)$$

where  $f_a$  denotes the focal length of the front lens group  $G_{2-1}$  and  $f_b$  denotes the focal length of the rear lens group  $G_{2-2}$ .

Conditional expression (2) defines an  
5 appropriate range of the ratio of refractive power of the front lens group  $G_{2-1}$  to that of the rear lens group  $G_{2-2}$  in the second lens group  $G_2$ . In the second lens group  $G_2$  according to the present invention, it is preferable that difference of refractive power  
10 between the front lens group  $G_{2-1}$  and the rear lens group  $G_{2-2}$  does not become excessively large as is the case of a Gauss type power arrangement. In other words, it is desirable for obtaining high optical performance and an increase in productivity to secure  
15 the symmetry of the refractive power arrangement within the scope of conditional expression (2).

When the ratio  $f_b/f_a$  exceeds the upper limit of conditional expression (2), refractive power of the front lens group  $G_{2-1}$  becomes excessively strong  
20 relative to that of the rear lens group  $G_{2-2}$ . Accordingly, the second lens group  $G_2$  becomes near to a lens type of an Ernostar that power arrangement is not symmetry. Therefore, each lens element in the front lens group  $G_{2-1}$  becomes sensitive to decentering,  
25 so that it becomes difficult to accomplish an increase in productivity, a decrease in manufacturing cost and compactness. When the upper limit of

conditional expression (2) is set to 10.0 or less, an increase in productivity, lowering manufacturing cost, and compactness can be accomplished. Moreover, when the upper limit of conditional expression (2) set to  
5 7.0 or less, the effect of the present invention brings into full play.

On the other hand, when the ratio  $f_b/f_a$  falls below the lower limit of conditional expression (2), refractive power of the rear lens group  $G_{2-2}$  becomes  
10 extremely strong relative to that of the front lens group  $G_{2-1}$  contrary to the former case. Accordingly, the second lens group becomes near to a lens type that power arrangement is not symmetry. Therefore, each lens element in the rear lens group  $G_{2-2}$  becomes  
15 sensitive to decentering. Moreover, spherical aberration and upper coma becomes worse, so that it becomes difficult to correct aberrations. Furthermore, the second lens group tends to become large. Accordingly, it becomes difficult to accomplish high  
20 optical performance, an increase in productivity, a decrease in manufacturing cost and compactness. When the lower limit of conditional expression (2) is set to 1.0 or more, further high optical performance, an increase in productivity and compactness can be  
25 accomplished. Moreover, when the lower limit of conditional expression (2) is set to 1.2 or more, the effect of the present invention brings into full play.

In a zoom lens system according to the present invention, the following conditional expression (3) is preferably satisfied:

$$0 < n_{an} - n_{ap} < 0.45 \quad (3)$$

5 where  $n_{ap}$  denotes refractive index of the positive lens  $L_{ap}$  of the cemented lens in the front lens group  $G_{2-1}$  at d-line ( $\lambda=587.56\text{nm}$ ), and  $n_{an}$  denotes refractive index the negative lens  $L_{an}$  of the cemented lens in the front lens group  $G_{2-1}$  at d-line ( $\lambda=587.56\text{nm}$ ).

10 Conditional expression (3) defines an appropriate range of difference of refractive index between the negative lens  $L_{an}$  and the positive lens  $L_{ap}$  of the cemented lens in the front lens group  $G_{2-1}$ .

When the value  $n_{an} - n_{ap}$  is equal to or exceeds the upper limit of conditional expression (3), refractive index of the positive lens  $L_{ap}$  becomes too small, so that the lens have to be thicker to secure the edge thickness of the periphery of the lens. Moreover, it becomes difficult to correct spherical aberration, so it is undesirable. When the upper limit of conditional expression (3) is set to 0.4 or less, it is effective to accomplish high optical performance, compactness, and a small diameter. When the upper limit of conditional expression (3) is set to 0.35 or less, the effect of the present invention brings into full play.

On the other hand, when the value  $n_{an} - n_{ap}$  is

equal to or falls below the lower limit of conditional expression (3), the magnitude relation of refractive index between the negative lens  $L_{an}$  and the positive lens  $L_{ap}$  is reversed and refractive index of the negative lens  $L_{an}$  becomes smaller than that of the positive lens  $L_{ap}$ . Accordingly, it becomes difficult for the zoom lens system according to the present invention to set Petzval sum to the optimum value. Therefore, it becomes difficult to correct astigmatism and curvature of field, and as a result, it becomes difficult to make the lens to be wide-angle. When the lower limit of conditional expression (3) is set to 0.1 or more, it is effective to accomplish high optical performance, compactness, and a small diameter. When the lower limit of conditional expression (3) is set to 0.25 or more, the effect of the present invention brings into full play.

In a zoom lens system according to the present invention, the following conditional expression (4) is preferably satisfied:

$$0 < n_{bn} - n_{bp} < 0.45 \quad (4)$$

where  $n_{bn}$  denotes refractive index of the negative lens  $L_{bn}$  of the cemented lens in the rear lens group  $G_{2-2}$  at d-line ( $\lambda=587.56\text{nm}$ ), and  $n_{bp}$  denotes refractive index of the positive lens  $L_{bp}$  of the cemented lens in the rear lens group  $G_{2-2}$  at d-line ( $\lambda=587.56\text{nm}$ ).

Conditional expression (4) defines an



appropriate range of difference of refractive index between the negative lens  $L_{bn}$  and the positive lens  $L_{bp}$  of the cemented lens in the rear lens group  $G_{2-2}$ .

When the value  $n_{bn}-n_{bp}$  is equal to or exceeds the upper limit of conditional expression (4), refractive index of the positive lens  $L_{bp}$  becomes too small, so that the lens have to be thicker to secure the edge thickness of the periphery of the lens. Moreover, it becomes difficult to correct spherical aberration, so it is undesirable. When the upper limit of conditional expression (4) is set to 0.4 or less, it is effective to accomplish high optical performance, compactness, and a small diameter. When the upper limit of conditional expression (4) is set to 0.35 or less, the effect of the present invention brings into full play.

On the other hand, when the value  $n_{bn}-n_{bp}$  is equal to or falls below the lower limit of conditional expression (4), the magnitude relation of refractive index between the negative lens  $L_{bn}$  and the positive lens  $L_{bp}$  is reversed and refractive index of the negative lens  $L_{bn}$  becomes smaller than that of the positive lens  $L_{bp}$ . Accordingly, it becomes difficult for the zoom lens system according to the present invention to set Petzval sum to the optimum value. Therefore, it becomes difficult to correct astigmatism and curvature of field, and as a result,

it becomes difficult to make the lens to be wide-angle. When the lower limit of conditional expression (4) is set to 0.1 or more, it is effective to accomplish high optical performance, compactness, and a small diameter. When the lower limit of conditional expression (4) is set to 0.25 or more, the effect of the present invention brings into full play.

In a zoom lens system according to the present invention, the aperture stop is preferably arranged between the front lens group  $G_{2-1}$  and the rear lens group  $G_{2-2}$ . By arranging the aperture stop at this position, symmetry of the second lens group relative to the aperture stop can be secured. This is effective for correcting aberrations preferably, so that the effect of the present invention brings into full play.

In a zoom lens system according to the present invention, the following conditional expression (5) is preferably satisfied:

$$v_{1p} < 23.2 \quad (5)$$

where  $v_{1p}$  denotes Abbe number of a positive lens  $L_{1p}$  in the first lens group  $G_1$ .

Conditional expression (5) defines an appropriate range of Abbe number of the positive lens  $L_{1p}$  in the first lens group  $G_1$ . When the number of lens elements is reduced as less as possible like a zoom lens system according to the present invention,

it is effective that the positive lens  $L_{1p}$  is made of a special glass material that is rarely used. In particular, in order to preferably correct lateral chromatic aberration and axial chromatic aberration in a well-balanced manner up to large angle of view, it is necessary to use extremely high dispersion glass. Accordingly, when conditional expression (5) is not satisfied, a zoom lens system having an extremely few number of lens elements in the first lens group including a wide-angle range with compactness and good productivity cannot be accomplished.

In a zoom lens system according to the present invention, the following conditional expression (6) is preferably satisfied:

$$1.790 < n_{1p} \quad (6)$$

where  $n_{1p}$  denotes refractive index of the positive lens  $L_{1p}$  in the first lens group at d-line ( $\lambda=587.56\text{nm}$ ).

Conditional expression (6) defines an appropriate range of refractive index of the positive lens  $L_{1p}$  in the first lens group. When the number of lens elements is reduced as less as possible like a zoom lens system according to the present invention, it is necessary that the positive lens  $L_{1p}$  is made of a glass material having high refractive index. In particular, in order to preferably correct lower coma

and spherical aberration in the telephoto state, it is necessary to use a glass material having extremely high refractive index. Accordingly, when conditional expression (6) is not satisfied, a zoom lens system  
5 having an extremely few number of lens elements in the first lens group including a wide-angle range with compactness and good productivity cannot be accomplished.

Numerical examples according to the present  
10 invention is explained below with reference to accompanying drawings.

<Example 1>

Fig. 1 is a diagram showing the lens arrangement of a zoom lens system according to Example 1 of the  
15 present invention together with movement of each lens group.

The zoom lens system according to Example 1 is a negative-positive two-group zoom lens system composed of, in order from an object, a first lens group G1  
20 having negative refractive power and a second lens group G2 having positive refractive power.

The first lens group G1 is composed of, in order from the object, a negative meniscus lens  $L_1$  having a convex surface facing to the object, and a positive  
25 meniscus lens  $L_{1p}$  having a convex surface facing to the object. The negative meniscus lens  $L_1$  is a compound lens constructed by glass and resin. Resin

is arranged on the image side surface of the lens.  
The image side surface of the resin is an aspherical surface.

The second lens group G2 is composed of, in  
5 order from the object, a front lens group  $G_{2-1}$ , an aperture stop S, a rear lens group  $G_{2-2}$ , and a fixed stop FS.

The front lens group  $G_{2-1}$  is composed of, in  
order from the object, a double convex positive lens  
10  $L_a$ , and a cemented negative lens constructed by a double convex positive lens  $L_{ap}$  cemented with a double concave negative lens  $L_{an}$ .

The rear lens group  $G_{2-2}$  is composed of, in order  
from the object, a cemented positive lens constructed  
15 by a negative meniscus lens  $L_{bn}$  having a convex surface facing to the object cemented with a double convex positive lens  $L_{bp}$ .

In a zoom lens system according to Example 1 of  
the present invention, when the state of lens group  
20 positions varies from a wide-angle end state (W) to a telephoto end state (T), zooming is carried out by moving the first lens group G1 and the second lens group G2 such that an air space  $D_s$  between the first lens group G1 and the second lens group G2 decreases.

25 In a zoom lens system according to Example 1 of the present invention, focusing to a close object is carried out by moving the first lens group G1 to the

object side.

Various values according to Example 1 are shown in Table 1.

In [Specifications],  $f$  denotes the focal length,   
 5  $A$  denotes a half angle of view, and FNO denotes an f-number.

In [Lens Data], the left most column shows the surface number that is a lens surface counted in order from the object,  $r_i$  denotes the radius of curvature of an  $i$ -th lens surface  $R_i$  counted in order   
 10 from the object,  $d_i$  denotes a distance along the optical axis between the lens surfaces  $R_i$  and  $R_{i+1}$ ,  $v_i$  denotes Abbe number of the medium between the lens surfaces  $R_i$  and  $R_{i+1}$ , and  $n_i$  denote refractive index   
 15 of a medium between the lens surfaces  $R_i$  and  $R_{i+1}$  at d-line ( $\lambda=587.56\text{nm}$ ).

In a zoom lens system according to Example 1 of the present invention, an aspherical surface is expressed by the following expression;

$$20 \quad S(y) = (y^2/R) / [1 + (1 - \kappa \cdot (y^2/R^2))^{1/2}] \\ + C4 \cdot y^4 + C6 \cdot y^6 + C8 \cdot y^8 + C10 \cdot y^{10}$$

where  $y$  denotes a height from the optical axis,  $S(y)$  denotes a distance (sag amount) along the optical axis from tangent plane at the vertex of the   
 25 aspherical surface to the aspherical surface at the height  $y$ ,  $R$  denotes a radius of curvature of a reference sphere (a paraxial radius of curvature),  $\kappa$

denotes a conical coefficient, and  $C_n$  denote  $n$ -th order aspherical coefficient, respectively.

An aspherical surface is denoted by an asterisk (\*) attached to the surface number, its paraxial radius of curvature is shown in column "r", and  $\kappa$  and each aspherical coefficient are shown in [Aspherical Data].

In [Aspherical Data], "E- $n$ " denotes " $10^{-n}$ ".

In [Variable Intervals],  $\beta$  denotes a magnification of the image relative to the object, 1-Pos denotes wide-angle end state focusing at infinity, 2-Pos denotes intermediate focal length state focusing at infinity, 3-Pos denotes telephoto end state focusing at infinity, 4-Pos denotes wide-angle end state at  $\beta = -0.02500$ , 5-Pos denotes intermediate focal length state at  $\beta = -0.02500$ , 6-Pos denotes telephoto end state at  $\beta = -0.02500$ , 7-Pos denotes wide-angle end state focusing at the closest object, 8-Pos denotes intermediate focal length state focusing at the closest object, and 9-Pos denotes telephoto end state focusing at the closest object.

In the tables for various values, "mm" is generally used for the unit of length such as the focal length, the radius of curvature, and the separation between optical surfaces. However, since an optical system proportionally enlarged or reduced its dimension can be obtained similar optical

performance, the unit is not necessary to be limited to "mm" and any other suitable unit can be used. The explanation of reference symbols is the same in the other example.

5 Table 1

[Specifications]

f= 18.5 - 53.4 mm

A= 38.3 - 14.92°

FNO=3.6 - 5.9

10 [Lens Data]

Surface

	Number	r	d	$\nu$	n
	1)	104.6196	1.8000	49.61	1.772500
	2)	16.5000	0.2000	38.70	1.552230
15	3*)	12.5393	12.8848		
	4)	30.9426	2.5000	22.76	1.808090
	5)	53.5711	D5		
	6)	39.6792	2.5000	55.38	1.638540
	7)	-84.1825	0.1000		
20	8)	22.4687	3.5000	64.10	1.516800
	9)	-37.9526	0.8000	46.58	1.804000
	10)	46.5681	2.5000		
	11>		8.0718		Aperture Stop S
	12)	104.9126	0.8000	37.17	1.834000
25	13)	15.2108	4.0000	64.10	1.516800
	14)	-26.1886	2.0000		
	15)		D15		Fixed Stop FS



[Aspherical Data]

Surface Number 3

$$\kappa = -0.4789$$

$$C4 = 4.27070E-05$$

$$5 \quad C6 = -7.03220E-08$$

$$C8 = 1.22200E-10$$

$$C10 = -2.85230E-13$$

[Variable Intervals]

		1-POS	2-POS	3-POS
10	f	18.50000	31.50000	53.40000
	D0	$\infty$	$\infty$	$\infty$
	D5	41.36450	16.06721	1.30316
	D15	38.25595	53.11309	78.14166
		4-Pos	5-Pos	6-Pos
15	$\beta$	-0.02500	-0.02500	-0.02500
	D0	711.2012	1231.2011	2107.2011
	D5	42.70538	16.85471	1.76770
	D15	38.25595	53.11309	78.14166
		7-POS	8-POS	9-POS
20	$\beta$	-0.07295	-0.11922	-0.21041
	D0	224.8104	235.4075	224.9888
	D5	45.27701	19.82280	5.21293
	D15	38.25595	53.11309	78.14166

[Values for Conditional Expressions]

25	(1) $D_s/D =$	0.436
	(2) $f_b/f_a =$	3.28
	(3) $n_{an}-n_{ap} =$	0.287

$$(4) n_{bn} - n_{bp} = 0.317$$

$$(5) v_{1p} = 22.8$$

$$(6) n_{1p} = 1.808$$

Figs. 2, 3, and 4 graphically show various aberrations of the zoom lens system according to Example 1 in a wide-angle end state, an intermediate focal length state, and a telephoto end state, respectively, when the zoom lens system is focused at infinity.

In respective graphs, FNO denotes the f-number, and A denotes a half angle of view (unit: degree). In the graph showing spherical aberration, f-number shows the value at the maximum aperture. In the graphs showing astigmatism and distortion, the maximum value of a half angle of view A is shown. In the graph showing astigmatism, a solid line indicates a sagittal image plane and a broken line indicates a meridional plane. The above-described explanation regarding various aberration graphs is the same as the other example.

As is apparent from the respective graphs, the zoom lens system according to Example 1 shows superb optical performance as a result of good corrections to various aberrations in each focal length state (the wide-angle end state, the intermediate focal length state, and the telephoto end state).

<Example 2>

Fig. 5 is a diagram showing the lens arrangement of a zoom lens system according to Example 2 of the present invention together with movement of each lens group.

5           The zoom lens system according to Example 2 is a negative-positive two-group zoom lens system composed of, in order from an object, a first lens group G1 having negative refractive power and a second lens group G2 having positive refractive power.

10           The first lens group G1 is composed of, in order from the object, a negative meniscus lens  $L_1$  having a convex surface facing to the object, and a positive meniscus lens  $L_{1p}$  having a convex surface facing to the object. The negative meniscus lens  $L_1$  is a  
15           compound lens constructed by glass and resin. Resin is arranged on the image side surface of the lens. The image side surface of the resin is an aspherical surface.

          The second lens group G2 is composed of, in  
20           order from the object, a front lens group  $G_{2-1}$ , an aperture stop S, a rear lens group  $G_{2-2}$ , and a fixed stop FS.

          The front lens group  $G_{2-1}$  is composed of, in  
order from the object, a double convex positive lens  
25            $L_a$ , and a cemented negative lens constructed by a double convex positive lens  $L_{ap}$  cemented with a double concave negative lens  $L_{an}$ .

The rear lens group  $G_{2-2}$  is composed of, in order from the object, a cemented positive lens constructed by a negative meniscus lens  $L_{bn}$  having a convex surface facing to the object cemented with a double convex positive lens  $L_{bp}$ .

In a zoom lens system according to Example 2 of the present invention, when the state of lens group positions varies from a wide-angle end state (W) to a telephoto end state (T), zooming is carried out by moving the first lens group  $G_1$  and the second lens group  $G_2$  such that an air space  $D_s$  between the first lens group  $G_1$  and the second lens group  $G_2$  decreases.

In a zoom lens system according to Example 2 of the present invention, focusing to a close object is carried out by moving the first lens group  $G_1$  to the object side.

Various values according to Example 2 are shown in Table 2.

Table 2

[Specifications]

$f = 18.5$       -      53.4 mm

$A = 38.3$       -       $14.92^\circ$

$FNO = 3.6$       -      5.9

[Lens Data]

Surface

Number	r	d	$\nu$	n
1)	86.5539	1.8000	49.61	1.772500

	2)	16.0000	0.2000	38.70	1.552230
	3*)	12.1665	10.7995		
	4)	26.9923	2.5000	22.76	1.808090
	5)	44.6158	D5		
5	6)	38.5505	2.5000	55.38	1.638540
	7)	-55.9183	0.1000		
	8)	18.6738	3.5000	64.10	1.516800
	9)	-32.6160	0.8000	46.58	1.804000
	10)	26.8523	2.5000		
10	11>		8.2839		Aperture Stop S
	12)	85.5647	0.8000	37.17	1.834000
	13)	16.4881	4.0000	64.10	1.516800
	14)	-23.7659	0.0000		
	15)		D15		Fixed Stop FS
15	[Aspherical Data]				
	Surface Number 3				
	$\kappa = -0.5076$				
	C4= 5.17550E-05				
	C6= -5.62150E-08				
20	C8= 5.34710E-11				
	C10= -2.24340E-13				
	[Variable Intervals]				
		1-POS	2-POS	3-POS	
	f	18.50000	31.50000	53.40000	
25	D0	$\infty$	$\infty$	$\infty$	
	D5	40.23414	15.63955	1.28562	
	D15	38.95217	53.39662	77.72995	

	4-Pos	5-Pos	6-Pos
$\beta$	-0.02500	-0.02500	-0.02500
D0	710.5943	1230.5943	2106.5943
D5	41.57502	16.42705	1.75016
5 D15	38.95217	53.39662	77.72995
	7-POS	8-POS	9-POS
$\beta$	-0.07154	-0.11715	-0.20636
D0	229.1933	239.4904	229.366
D5	44.07117	19.32964	5.12007
10 D15	38.95217	53.39662	77.72995

[Values for Conditional Expressions]

- (1)  $D_s/D = 0.480$
- (2)  $f_b/f_a = 1.76$
- (3)  $n_{an}-n_{ap} = 0.287$
- 15 (4)  $n_{bn}-n_{bp} = 0.317$
- (5)  $v_{1p} = 22.8$
- (6)  $n_{1p} = 1.808$

Figs. 6, 7, and 8 graphically show various aberrations of the zoom lens system according to Example 2 in a wide-angle end state, an intermediate focal length state, and a telephoto end state, respectively, when the zoom lens system is focused at infinity.

As is apparent from the respective graphs, the zoom lens system according to Example 2 shows superb optical performance as a result of good corrections to various aberrations in each focal length state

(the wide-angle end state, the intermediate focal length state, and the telephoto end state).

<Example 3>

Fig. 9 is a diagram showing the lens arrangement  
5 of a zoom lens system according to Example 3 of the present invention together with movement of each lens group.

The zoom lens system according to Example 3 is a  
negative-positive two-group zoom lens system' composed  
10 of, in order from an object, a first lens group G1 having negative refractive power and a second lens group G2 having positive refractive power.

The first lens group G1 is composed of, in order from the object, a negative meniscus lens L<sub>1</sub> having a  
15 convex surface facing to the object, and a positive meniscus lens L<sub>1p</sub> having a convex surface facing to the object. The negative meniscus lens L<sub>1</sub> is a compound lens constructed by glass and resin. Resin is arranged on the image side surface of the lens.  
20 The image side surface of the resin is an aspherical surface.

The second lens group G2 is composed of, in order from the object, a front lens group G<sub>2-1</sub>, an  
aperture stop S, a rear lens group G<sub>2-2</sub>, and a flare  
25 stopper F.

The front lens group G<sub>2-1</sub> is composed of, in order from the object, a double convex positive lens

$L_a$ , and a cemented negative lens constructed by a double convex positive lens  $L_{ap}$  cemented with a double concave negative lens  $L_{an}$ .

5 The rear lens group  $G_{2-2}$  is composed of, in order from the object, a cemented negative lens constructed by a negative meniscus lens  $L_{bn}$  having a convex surface facing to the object cemented with a double convex positive lens  $L_{bp}$ , and a double convex positive lens  $L_b$ .

10 In a zoom lens system according to Example 3 of the present invention, when the state of lens group positions varies from a wide-angle end state (W) to a telephoto end state (T), zooming is carried out by moving the first lens group  $G_1$  and the second lens  
15 group  $G_2$  such that an air space  $D_s$  between the first lens group  $G_1$  and the second lens group  $G_2$  decreases.

In a zoom lens system according to Example 3 of the present invention, focusing to a close object is carried out by moving the first lens group  $G_1$  to the  
20 object side.

The aforementioned flare stopper  $F$  has a fixed diameter and moves independently with the second lens group  $G_2$  upon zooming.

Various values according to Example 3 are shown  
25 in Table 3.

Table 3

[Specifications]



f= 18.5 - 53.4 mm

A= 38.2 - 14.93°

FNO=3.6 - 5.9

[Lens Data]

5 Surface

	Number	r	d	$\nu$	n
	1)	83.0076	1.8000	49.61	1.772500
	2)	16.5000	0.2000	38.70	1.552230
	3*)	12.6003	13.3087		
10	4)	28.5874	2.8000	22.76	1.808090
	5)	43.4120	D5		
	6)	28.4446	3.0000	55.38	1.638540
	7)	-79.3719	0.1000		
	8)	33.4115	3.5000	64.10	1.516800
15	9)	-31.0350	1.0000	46.58	1.804000
	10)	65.3951	2.0000		
	11>		8.0718		Aperture Stop S
	12)	-28.2267	1.0000	46.58	1.804000
	13)	21.7458	4.2000	82.52	1.497820
20	14)	-17.9528	0.1000		
	15)	91.5812	2.3000	70.41	1.487490
	16)	-47.8355	D16		
	17)		D17		Flare Stopper F

[Aspherical Data]

25 Surface Number 3

$\kappa = -0.9766$

C4= 7.59690E-05

C6= -1.78000E-07

C8= 4.03250E-10

C10=-5.80270E-13

[Variable Intervals]

5		1-POS	2-POS	3-POS
	f	18.50000	31.43000	53.40000
	D0	$\infty$	$\infty$	$\infty$
	D5	43.62877	17.01071	1.34180
	D16	0.00000	6.23924	16.84063
10	D17	41.78742	51.14628	67.04837
		4-Pos	5-Pos	6-Pos
	$\beta$	-0.02500	-0.02500	-0.02500
	D0	710.5710	1227.7709	2106.5709
	D5	44.96965	17.79996	1.80634
15	D16	0.00000	6.23924	16.84063
	D17	41.78742	51.14628	67.04837
		7-POS	8-POS	9-POS
	$\beta$	-0.07502	-0.12191	-0.21637
	D0	217.1797	228.3744	217.3682
20	D5	47.65235	20.85957	5.36231
	D16	0.00000	6.23924	16.84063
	D17	41.78742	51.14628	67.04837

[Values for Conditional Expressions]

- (1)  $D_s/D = 0.399$
- 25 (2)  $f_b/f_a = 4.17$
- (3)  $n_{an}-n_{ap} = 0.287$
- (4)  $n_{bn}-n_{bp} = 0.306$

(5)  $v_{1p} = 22.8$

(6)  $n_{1p} = 1.808$

Figs. 10, 11, and 12 graphically show various aberrations of the zoom lens system according to Example 3 in a wide-angle end state, an intermediate focal length state, and a telephoto end state, respectively, when the zoom lens system is focused at infinity.

As is apparent from the respective graphs, the zoom lens system according to Example 3 shows superb optical performance as a result of good corrections to various aberrations in each focal length state (the wide-angle end state, the intermediate focal length state, and the telephoto end state).

As described above, the present invention makes it possible to provide a zoom lens system having an angle of view of about  $2A=76.4^\circ - 29.9^\circ$ , a zoom ratio about 2.9, high cost performance, high optical performance, good productivity, and compactness of about a normal lens.

In a zoom lens system according to the present invention, sufficient effect of a vibration reduction lens can be obtained by shifting the front lens group  $G_{2-1}$  or the rear lens group  $G_{2-2}$  independently from the optical axis. Moreover, in a zoom lens system according to the present invention, sufficient effect of a vibration reduction lens can be obtained by

shifting the second lens group G2 from the optical axis.

Additional advantages and modification will readily occur to those skilled in the art. Therefore,  
5 the invention in its broader aspects is not limited to the specific details, and representative devices shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as  
10 defined by the appended claims and their equivalents.